



Published in final edited form as:

Accid Anal Prev. 2016 December ; 97: 132–140. doi:10.1016/j.aap.2016.08.028.

A behavioral economic analysis of texting while driving: Delay discounting processes

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Abstract

The purpose of the present study was to examine an impulsive decision-making process underlying texting while driving from a behavioral economic perspective. A sample of 108 college students completed a novel discounting task that presented participants with a hypothetical scenario in which, after receiving a text message while driving, they rated the likelihood of replying to a text message immediately versus waiting to reply for a specific period of time. Participants also completed a delay discounting task in which they made repeated hypothetical choices between obtaining a larger amount of money available after a delay and an equal or lesser amount of money available immediately. The results show that the duration of the delay is a critical variable that strongly determines whether participants choose to wait to reply to a text message, and that the decrease in the likelihood of waiting as a function of delay is best described by a hyperbolic delay discounting function. The results also show that participants who self-reported higher frequency of texting while driving discounted the opportunity to reply to a text message at greater rates, whereas there was no relation between the rates of discounting of hypothetical monetary rewards and the frequency of texting while driving. The results support the conclusion that texting while driving is fundamentally an impulsive choice.

Keywords

Texting while driving; Distracted driving; Delay discounting; Impulsivity; Behavioral economics; College students

1. Introduction

It is estimated that 6–16% of motor vehicle crashes in the United States in 2013 were due to text messaging (National Safety Council, 2015). Despite 46 states adopting legislation to ban text messaging (Governors Highway Safety Association, 2016) and various educational campaigns that increase awareness of the danger of texting while driving (e.g., Sherin et al., 2014), texting while driving remains a major problem in traffic safety. According to the Centers for Disease Control and Prevention (2013), 31.2% of drivers aged 18–64 years in the

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United States reported that they had engaged in texting while driving in the past 30 days. It is particularly pervasive among young drivers; more than 90% of college students reported having texted while driving (e.g., Atchley et al., 2011).

In an attempt to predict who is at risk of texting while driving, previous research has identified various psychological factors associated with this risky behavior. These factors include impulsivity (e.g., Quisenberry, 2015), habitual texting tendencies (e.g., Bayer and Campbell, 2012), cell-phone dependency (e.g., Struckman-Johnson et al., 2015), perceived need for a cell phone while driving (e.g., Musicant et al., 2015), perceived texting distractibility (only for males; Struckman-Johnson et al., 2015), risky behavior tendencies (only for females; Struckman-Johnson et al., 2015), and low levels of mindfulness (e.g., Feldman et al., 2011).

Although previous studies have made progress in identifying psychological predictors for texting while driving, the underlying behavioral and cognitive processes of texting while driving remain unknown. For example, one hallmark of texting while driving is that drivers engage in the behavior despite being aware of its dangers (Atchley et al., 2011). This tendency may explain why legislation to ban texting while driving and education on its dangers have not reduced texting while driving (Ehsani et al., 2014; Goodwin et al., 2012). The decision-making processes that influence drivers to continue engaging in such a risky behavior despite knowledge of its dangers warrant further investigation.

One framework that may be useful for understanding the persistent nature of texting while driving is a behavioral economic approach. Behavioral economics refers to the application of economic concepts and approaches to the study of individuals' choices and decisions controlled by reinforcement contingencies operating over extended periods of time (Bickel et al., 2014). When drivers engage in texting while driving, they make a choice between immediate text messaging (ultimately less valuable given the increased risk of a motor vehicle crash) and withholding text messaging and waiting some length of time until arriving at the destination (ultimately more valuable given safety). From a behavioral economic perspective, texting while driving can be viewed as an impulsive choice toward a smaller-sooner reward (i.e., immediate short text message) at the expense of safety. One potential explanation for this preference toward a smaller-sooner reward is delay discounting—the process by which the decision maker subjectively devalues future events (Madden and Bickel, 2010). An impulsive choice is made because the subjective value of a reward is discounted as the delay to its receipt increases (see Green and Myerson, 2004; for review). A large literature draws important connections between choice patterns using discounting tasks and a range of impulsivity-related problems, including substance dependence and abuse (MacKillop et al., 2011), obesity (e.g., Epstein et al., 2010), pathological gambling (e.g., Petry and Madden, 2010), internet addiction (e.g., Saville et al., 2010), HIV-risk behavior such as needle sharing (e.g., Odum et al., 2000), risky sexual behavior (e.g., Chesson et al., 2006), and criminal behavior (e.g., Arantes et al., 2013).

The extensive literature linking delay discounting and various impulsivity-related problems provides a compelling rationale to examine discounting as a potential mechanism that underlies texting while driving. Hayashi et al. (2015) recently reported patterns of delay

discounting in relation to texting while driving. Using a delay discounting task with hypothetical monetary rewards, they compared the degree of delay discounting between college students who frequently text while driving and those who infrequently text while driving. They found that the rate of delay discounting of monetary rewards was greater for participants who frequently text while driving, suggesting that texting while driving is associated with impulsive decisions. Despite this evidence, it is not clear how the delay associated with texting per se (e.g., having an opportunity to reply to a text message after a delay) affects drivers' decision to engage in such a risky behavior. Further investigation is needed to better understand behavioral and cognitive processes underlying drivers' decision to text while driving.

To date, two studies have investigated the role of delay discounting in decision-making processes associated with general texting behavior (i.e., not specifically texting while driving). Using hypothetical scenarios, Atchley and Warden (2012) presented college students with a series of choices between one option to receive a smaller amount of money (e.g., \$5) and reply to a text message immediately and another option to receive a larger amount of money (\$100) and reply to a message after a delay (e.g., 60 min). Also using hypothetical scenarios, Reed et al. (2016) presented 18 to 64-year-old participants recruited via Amazon Mechanical Turk with a series of choices between one option to pay a small amount of money (e.g., \$5) and read and reply to a text message immediately and another option to read and reply to a text message after a delay (e.g., 60 min) for free. In both studies, the likelihood of waiting to engage in texting decreased as the delay increased. In addition, the shape of the delay discounting function closely resembled that of hypothetical monetary rewards commonly reported in the literature.

Although these previous studies show that delay discounting occurs when individuals make decisions in some general texting scenarios, it is still unknown whether delay discounting is a major process that underlies drivers' decisions to engage in texting while driving. In addition, the delay discounting task in the previous studies involved both hypothetical money (gain or loss) and hypothetical opportunity to engage in texting (send or read/reply). Because drivers typically do not text while driving for monetary gains or losses, further investigation is needed to determine whether the *value* of texting behavior, like the value of monetary rewards, is directly affected by delays in opportunities to read or reply to them.

The first purpose of the present study was to determine whether decision making concerning texting while driving could be well characterized using the discounting paradigm. Based on the well validated Sexual Delay Discounting Task developed by Johnson and his colleagues (e.g., Johnson and Bruner, 2012, 2013; Johnson et al., 2015), we developed a novel delay discounting task that presented drivers with a hypothetical scenario in which, after receiving a text message while driving, they were asked to rate the likelihood of replying to a text message immediately versus waiting to reply for a specific period of time. It was hypothesized that the subjective value of opportunities to respond to a text message received while driving will be discounted as a function of the delay (i.e., waiting time).

The second purpose of the present study was to test three mathematical models of delay discounting to determine which model best describes the discounting process in texting while driving. Eq. (1) is an exponential model (Samuelson, 1937):

$$V = Ae^{-kD}, \quad (1)$$

where V refers to the subjective or discounted value of a delayed reward, A refers to the reward amount, D refers to the delay to the reward, and k is a free parameter that reflects the rate of discounting. Higher k values indicate greater discounting and thus greater impulsivity (Bickel and Marsch, 2001). The exponential model is based on normative economic theory (Lancaster, 1963), and it predicts a constant rate of discounting across delays to receiving an outcome.

Eq. (2) is a hyperbolic model (Mazur, 1987):

$$V = \frac{A}{1+kD}, \quad (2)$$

where the parameters are the same as in Eq. (1). The hyperbolic model predicts a disproportional rate of discounting across different delays (i.e., the rate of discounting decreases as delay increases).

Eq. (3) is a hyperboloid model (Myerson and Green, 1995):

$$V = \frac{A}{1+kD^s}. \quad (3)$$

This equation is the same as Eq. (2) except for the inclusion of a free parameter s that reflects sensitivity to delay. Indeed, when the value of s is 1.0, Eq. (3) can be reduced to Eq. (2).

Determining the form of discounting functions is important because it has important behavioral implications (Green and Myerson, 1996). First, different mathematical functions lead to different predictions regarding behavior. For example, both hyperbolic and hyperboloid functions predict the occurrence of *preference reversals*, which refer to a shift in preference from a larger-delayed reward to a smaller-immediate reward as the receipt of the reward approaches (Green et al., 1981). As mentioned previously, one hallmark of texting while driving is that drivers often engage in texting while driving despite being aware of its danger. This phenomenon may be accounted for by preference reversals (details will be discussed later). Second, the form of mathematical functions provides clues as to the mechanism underlying a behavior of interest because different mathematical functions assume different ways in which the behavior changes. For example, exponential discounting assumes that individuals will make rational choices that maximize utility, and once a choice is made, it remains constant over the delay (Madden and Johnson, 2010). By contrast, the

hyperbolic and hyperboloid functions do not assume rationality of choice; preferences may shift, or reverse, across different delays.

The third purpose of the present study was to investigate whether drivers who frequently text while driving discount an opportunity to reply to a text message received at a greater rate than those who infrequently text while driving. A previous study demonstrated that drivers who reported a high frequency of texting while driving discount hypothetical monetary rewards (Hayashi et al., 2015), but it is unknown whether such drivers will discount an opportunity to engage in texting while driving as a social reward. Three groups of participants that differed in terms of frequency of texting while driving were compared on the extent to which they discounted the opportunity to reply to a text message while driving. It was hypothesized that greater discounting will be associated with greater frequency of texting while driving: drivers who text while driving most frequently show the greatest rates of discounting.

Finally, the fourth purpose of the present study was to examine whether delay discounting involved in texting while driving is similar to delay discounting involved in choosing monetary rewards. If sensitivity to delayed outcomes is a pervasive individual characteristic (Odum, 2011a, 2011b), then individuals with such a characteristic should make impulsive choices regardless of outcomes to be discounted (see Bickel et al., 2012; for a discussion on delay discounting as a trait-like, trans-disease process). This view of delay discounting as a trait variable predicts that drivers who discount the opportunity to reply to a text message at a greater rate will also discount monetary rewards at a greater rate. On the other hand, if decision making for texting while driving is different from decision making for monetary rewards, which is consistent with the view of delay discounting as a state variable, then drivers who discount the opportunity to reply to a text message at a greater rate may not necessarily discount monetary rewards at a greater rate. Consistent with the results of Hayashi et al. (2015), which demonstrated that drivers who frequently text while driving discounted monetary rewards at a greater rate, it was hypothesized that individuals' delay discounting rates of opportunities to text while driving will be significantly correlated with that of monetary rewards.

2. Material and methods

2.1. Participants

One hundred and eight undergraduate students enrolled in an introductory psychology course at a university in the Northeastern United States participated. They were offered course credit for participation. Students who reported that they had no history of driving on the demographic survey ($N = 15$) were excluded from the study and their data were not analyzed. Students who reported contradictory information on their frequency of texting while driving (i.e., reporting that they always send a text message while driving but the number of days in which they sent a text message was 0 in the past 30 days; $N = 3$) were also excluded from the study. The remaining sample was composed of 37 male and 53 female students. Their mean age, years of higher education, and years driving were 19.7 ($SD = 3.4$; ranging from 18 to 42), 1.7 ($SD = 1.1$; from 1 to 6), and 3.5 ($SD = 3.2$; from 1 to 24), respectively.

2.2. Procedure

A session was hosted online by Qualtrics (Provo, UT). Participants received an email through the Qualtrics website that contained the link to the online tasks. After the participants agreed to participate, they completed a demographic questionnaire and two delay discounting tasks: one with a hypothetical scenario of texting while driving and the other with hypothetical monetary rewards. The Institutional Review Board at the Pennsylvania State University approved the study protocol.

2.2.1. Demographic questionnaire—The questionnaire collected information such as age, gender, years of higher education, and years driving, and included three questions on the number of days in which they initiated, read, or replied to a text message while driving during the past 30 days (e.g., “During the past 30 days, on how many days did you initiate a text while driving?”). The questionnaire also measured self-reported frequency and perceived danger of initiating, reading, and replying to a text message while driving using portions of a questionnaire developed by Atchley et al. (2011). The questionnaire employed a 7-point Likert scale ranging from 1 (*never*) to 7 (*always*) for Frequency and 1 (*not at all*) to 7 (*extremely*) for Perceived Danger.

Based on the mean days of initiating, reading, and replying to a text message during the past 30 days, the participants were assigned to either of High (top-third percentiles, $N = 30$), Middle (middle-third percentiles, $N = 30$), and Low (bottom-third percentiles, $N = 30$) groups. When more than one student reported the same mean days of texting while driving, the mean self-reported frequency of texting while driving was used for the group assignment. Only two participants reported the same days and frequency of texting while driving. Their group assignment was determined randomly by a coin toss.

2.2.2. Delay discounting task with a hypothetical opportunity to text—The task was based on the Sexual Delay Discounting Task developed by Johnson and his colleagues (e.g., Johnson et al., 2015). Using visual analog scales (VAS), participants rated their likelihood of replying to a text message immediately versus waiting to reply for a certain period of time. The task presented the following scenario:

Imagine that your significant other (or your best friend) has just sent a text message saying “text me asap” while you are driving at 40 mph. You will arrive at your destination in 30 s.

Please rate how likely you are to reply to the message now versus waiting for 30 s.

In this task, the VAS was a horizontal line labeled from 0 to 100 in increments of 10 with the descriptive anchors, *definitely reply now* and *definitely wait*. The VAS was located immediately below the instruction. The participants clicked on the slider and moved it across the horizontal line in order to indicate their likelihood of waiting until the destination. This scenario was presented six times with the only difference being the delay to the destination (30 s, 3 min, 15 min, 1 h, 2 h, and 6 h presented in this order). Each delay consisted of the same VAS (labeled 0–100 in increments of 10) presented on a separate screen.

2.2.3. Delay discounting task with a hypothetical monetary reward—The delay discounting procedure, which required participants to make decisions based on hypothetical monetary rewards, was adapted from Rachlin et al. (1991). Participants were asked to choose between a smaller amount of hypothetical money available immediately and a larger amount of hypothetical money available after some delay. There were seven delay values—1 week, 2 weeks, 1 month, 6 months, 1 year, 3 years, and 10 years—each presented on a separate screen. Participants made a total of 30 hypothetical choices for each of the seven delay values. On each screen, the smaller immediate rewards, ranging from \$1 to \$1000 (1, 5, 10, 20, 40, 60, 80, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 920, 940, 960, 980, 990, and 1000), were listed in ascending order in a column to the left and the larger delayed reward was presented in a column to the right. The larger reward was always \$1000 available after a fixed delay. Participants indicated the reward they preferred by clicking a radio button to the left of each reward value.

2.3. Data analysis

For demographic and texting-related measures, the data on ratio (e.g., age), ordinal (e.g., frequency of texting while driving), and categorical (e.g., gender) scales were analyzed with a one-way analysis of variance (ANOVA), a Kruskal-Wallis test, and a chi square test, respectively. For the delay discounting assessment, Eqs. (1)–(3) were fitted to both group and individual data using least squares nonlinear regression performed with the Solver function in Microsoft Excel 2013. The equations could not be fitted to data from eight participants because the likelihood of waiting did not differ across delays (e.g., a participant always chose to wait until destination). These data were excluded when analyzing the fit of the equations based on the data obtained from individual participants (Johnson and Bickel, 2008), although the data were included for the rest of the analyses. To compare the goodness of fit of the equations, values of Akaike Information Criterion with small sample correction (AIC_c ; Burnham and Anderson, 2002) were calculated at both group and individual levels. Smaller AIC_c values indicate better fits. Because AIC_c deals with the trade off between the goodness of fit of the equation and its complexity (i.e., the number of free parameters), it is ideal for comparison of equations that differ in the number of free parameters. Despite its frequent use, R^2 is not an adequate measure for the goodness of fit in nonlinear models (Spiess and Neumeyer, 2010). Therefore, we used AIC_c values only when comparing the goodness of fit of the equations (see Takahashi et al., 2008; for similar exclusive use of AIC_c values). Because the AIC_c values calculated by fitting each equation to individual participant data were not normally distributed, the comparison of the values across equations was performed with the Friedman test. Post-hoc comparisons were conducted with the Wilcoxon signed-rank test with Bonferroni correction. To compare the degree of delay discounting across groups that differed in frequency of texting while driving, the area under the discounting curve (AUC), a descriptive, non-theoretical measure of discounting, was calculated for each participant based on the method described by Myerson et al. (2001). For the delay discounting task with hypothetical money, the AUC was calculated based on indifference points—the points at which the subjective value of the smaller immediate reward and the larger delayed reward are equivalent. Indifference points were calculated using the method described by Rachlin et al. (1991). The comparison of the AUC values across groups was performed with the Kruskal-Wallis test because the data were not

normally distributed. Post-hoc comparisons were conducted using the Mann-Whitney test with Bonferroni correction. Finally, correlational analyses among all the demographics and both delay discounting measures were performed by calculating Pearson correlation coefficients. All statistical analyses were performed with SPSS Version 23. The statistical significance level for all tests was set at 0.05.

3. Results

Table 1 shows the demographic characteristics, self-reported days and frequency, and perceived danger of texting while driving for the three groups. Significant differences between groups were found for self-reported days of texting while driving, $F(2, 87) = 111.97, p < 0.001$; and self-reported frequency of texting while driving, $\chi^2(2) = 38.97, p < 0.001$. No significant differences between groups were found for gender, $\chi^2(2) = 3.95, p = 0.139$; age, $F(2, 87) = 0.08, p = 0.923$; years of higher education, $F(2, 87) = 0.78, p = 0.463$; years driving, $F(2, 87) = 0.29, p = 0.747$; and perceived danger of texting while driving, $\chi^2(2) = 5.99, p = 0.050$.

Fig. 1 shows the group median and the 25th and 75th percentiles of likelihood of waiting until the destination and best-fitting discounting functions for Eqs. (1) through (3). The data are the group aggregates that include the 90 participants. In general, the likelihood of waiting decreased as a function of delay until the destination, suggesting that the value of the opportunity to reply to a text message as a reward is subject to delay discounting. With respect to the goodness of the fits of the equations, the AIC_c values for all 25th percentile, median, and the 75th percentile were lowest with the hyperbolic equation, followed by the hyperboloid equation (see Fig. 1).

To further compare the quality of the fit, each equation was fitted to the data obtained from each participant. The exponential and hyperbolic equations provided better fits to the individual data: a significant difference in AIC_c values was found among Equations ($\chi^2(2) = 79.63, p < 0.001$). Post-hoc comparisons showed significant differences between the exponential and hyperboloid functions ($Z = 6.20, p < 0.001, r = 0.68$) and between the hyperbolic and hyperboloid functions ($Z = 7.01, p < 0.001, r = 0.77$), but not between the exponential and hyperbolic functions ($Z = -0.53, p = 0.600, r = 0.06$). Visual inspection of the AIC_c values indicated a superior fit for the hyperbolic equation in 47 out of 82 cases (57.3%) over the exponential equation. Assuming each equation is equally likely to be the better fit to individual data ($p = 0.5$), binomial probability that the hyperbolic equation produces a better fit by chance in 47 or more out of 82 cases is only 0.11. Based on these results and the results of the group data, we concluded that the hyperbolic discounting equation was the best choice for describing the present data sets.

Fig. 2 shows the median likelihood of waiting as a function of delay until the destination for the three groups that differ in self-reported days of texting while driving. The curves were plotted as hyperbolic functions only. Visual analysis of the figure reveals that the rate of discounting was much greater for High and Middle groups than for the Low group.

To further analyze the difference between groups, the AUC was calculated based on the data obtained from each participant. The upper panel of Fig. 3 shows median AUC based on the likelihood of waiting for the three groups. A significant main effect of Group on AUC was revealed ($\chi^2(2) = 22.74, p < 0.001$). Post-hoc comparisons showed significant differences between the High and Low groups ($U = 127.00, p < 0.001, r = 0.62$) and between the Middle and Low groups ($U = 265.50, p = 0.018, r = 0.35$).

The AUC, based on the indifference points obtained from delay discounting of hypothetical monetary rewards, was also calculated for each participant. The lower panel of Fig. 3 shows median AUC for the three groups. Unlike the AUC based on the likelihood of waiting, no significant main effect of Group on AUC based on the monetary rewards was revealed ($\chi^2(2) = 0.00, p = 0.998$).

Table 2 shows Pearson correlation coefficients of the demographic characteristics and the delay discounting measure. This analysis was conducted because splitting the participants into three groups instead of two, four, or n groups is somewhat arbitrary. Consistent with the data in Fig. 2 and the upper panel of Fig. 3, the AUC based on the likelihood of waiting was significantly negatively correlated with both self-reported days of texting while driving, $r(88) = -0.42, p < 0.001$, and self-reported frequency of texting while driving, $r(88) = -0.45, p < 0.001$. On the other hand, the AUC based on the monetary rewards was not significantly correlated with either self-reported days of texting while driving, $r(88) = 0.05, p = 0.626$, or self-reported frequency of texting while driving, $r(88) = 0.06, p = 0.557$. In addition, the correlation between the AUC based on the likelihood of waiting and the AUC based on the monetary rewards was positive but not significant, $r(88) = 0.09, p = 0.398$. Second, the perceived danger of texting while driving was significantly negatively correlated with self-reported days of texting while driving, $r(88) = -0.32, p = 0.002$, but not with self-reported frequency of texting while driving, $r(88) = -0.15, p = 0.171$. Finally, the AUC based on the likelihood of waiting was not significantly correlated with the perceived danger, $r(88) = 0.17, p = 0.117$.

4. Discussion

The purpose of the present study was to examine an impulsive decision-making process underlying texting while driving from a behavioral economic perspective. To this end, we developed a novel delay discounting task using a hypothetical scenario in which participants rated their likelihood of immediately replying to a text message they received while driving versus waiting to reply until arriving at the destination. The likelihood of waiting decreased as a function of delay until the destination. In addition, this decrease in likelihood was well described by the hyperbolic function, suggesting that delay discounting is an underlying process of drivers' decision to engage in texting while driving. There were differences in discounting between the two types of outcomes. Drivers who self-reported more days of texting while driving showed greater rates of discounting the likelihood of waiting, although there was no difference in the rate of discounting of hypothetical monetary rewards among groups. The correlation of rates of delay discounting between the two types of outcomes was positive but weak.

All participants reported a high propensity to wait until their destination if the delay is very short (e.g., 30 s), but adding a relatively short delay (e.g., 15 min) greatly reduced the likelihood of waiting in the groups of participants who self-reported moderate and high number of days of texting while driving. This indicates that delay is a critical variable in drivers' decision to engage in texting while driving, and this novel delay discounting task appears to provide a practically meaningful assessment of this phenomenon. In addition, obtaining patterns of discounting that are similar to those of other frequently studied behavioral phenomena, such as substance abuse (MacKillop et al., 2011), would suggest that drivers make decisions regarding text messaging in a fundamentally similar manner to humans' and other animals' decisions regarding delayed reinforcers in general.

Several previous studies (e.g., Charlton and Fantino, 2008; Johnson et al., 2010; Odum, 2011b; Rasmussen et al., 2010) have reported significant positive correlations between discounting rates of one outcome (e.g., money) and another outcome (e.g., drug or food). It is important to note that these studies have also reported that delay discounting can depend on the nature of the outcome being discounted, as in the present study. Particularly, this domain specificity in delay discounting has been consistently observed between sexual and monetary outcomes when delay discounting of sexual outcomes was assessed in a similar procedure to the one used in the present study (Herrmann et al., 2014; Johnson and Bruner, 2012; Johnson et al., 2015). Perhaps delay discounting of an opportunity to reply to a text message and delay discounting of monetary reward involve different decision-making processes, which highlights the importance of investigating delay discounting processes with respect to the specific outcome associated with texting while driving.

Nevertheless, the results of the present study are inconsistent with those of Hayashi et al. (2015), who found that the group of students who frequently text while driving discounted hypothetical monetary rewards at a greater rate. This difference may be due to some methodological differences across these studies. For example, Hayashi et al. used a paper-and-pencil based task, whereas the present study used a computer-based task, although both studies used Rachlin et al.'s (1991) procedure. Another possibility is a sampling issue. The value of self-reported frequency of texting while driving of the high-frequency group is somewhat lower in the present study than in Hayashi et al.'s study. Although the grouping method was different and thus a direct comparison cannot be made, the mean self-reported frequency was 4.2 (Table 1) and 5.6 (Table 1 in Hayashi et al., 2015) for the present and Hayashi et al.'s studies, respectively. Perhaps, if the sample of the present study had involved students who text while driving more frequently, the results might have been different. Nevertheless, future research should determine whether the difference in these findings is due to study parameters.

4.1. Delay discounting as an underlying process

Most research on texting while driving has focused on identifying associated personality or demographic variables (e.g., impulsivity; Quisenberry, 2015). Therefore, the propensity to engage in texting while driving is often treated as a trait variable that is best investigated with between-subject experimental designs (i.e., comparing groups). A finding of the present study—that the group of students who most frequently text while driving showed the

greatest rates of delay discounting of the hypothetical opportunity to reply to a text message—is consistent with this notion. Nevertheless, it is important to note that the domain specificity observed in this study supports the notion that the propensity to discount the value of the opportunity to reply to a text message is also a state-like variable that can be investigated with within-subjects designs (cf. Odum, 2011a, 2011b). Accordingly, it is noteworthy that even the group of drivers who most frequently text while driving showed the greater likelihood of waiting to reply to a text message when the delay to the destination was short, and minor manipulations in delay (e.g., increase from 5 min to 15 min) showed a robust decrease in the likelihood of waiting to reply (see Fig. 2).

One way to characterize such within-subject changes is the notion of *preference reversals*. To illustrate how texting while driving involves a preference reversal, consider the hypothetical scenario involving a choice between two opportunities to text: a sooner opportunity to text while driving with a risk of a motor vehicle crash (sooner-risky opportunity) and a later opportunity to text after arriving at a destination without a risk of a crash (later safe opportunity) shown in Fig. 4 (cf. see Hayashi et al., 2015; for an alternative way of conceptualizing preference reversal in texting while driving). Note that, unlike Figs. 1 and 2, Fig. 4 depicts changes in the subjective value of the opportunity to text as a reward as a function of time. Time A depicts the moment when the sooner-risky opportunity is available (white bar) and Time B depicts the moment when the later-safe opportunity is available (black bar). The length of the bars represents the subjective value of the opportunities (i.e., the safer opportunity has higher subjective value). Hypothetical delay-discounting functions show how the subjective value of the sooner-risky opportunity (dashed line) and the later-safe opportunity (solid line) changes as a function of time. Preference reversals occur only when rates of discounting are moderately high and Fig. 4 shows such a case (i.e., case for the High group in Fig. 2). When the availability of both opportunities is temporally remote (e.g., a text message that does not need an immediate reply) at Time C, drivers would place a greater value on the later-safe opportunity over the sooner-risky opportunity. On the other hand, at Time D when the availability of the sooner-risky opportunity is temporally proximate (e.g., receiving a text message while driving), impulsive drivers place a greater value on the sooner-risky opportunity over the later-safe opportunity after a preference reversal.

Because drivers who frequently text while driving discount the value of a delayed opportunity to reply to a text message to a greater extent, they may devalue the benefits of safety to such a degree that these devalued benefits cannot adequately compete with the immediately rewarding consequences of texting while driving after a preference reversal. This may explain why drivers engage in texting while driving despite being aware of its dangers (Atchley et al., 2011; see also Table 1). Indeed, a number of addictive disorders, such as substance abuse, are also characterized by a persistent desire for self-control and repeated failures to achieve it (Madden and Johnson, 2010), and one proposed mechanism underlying the self-control failure is preference reversal (MacKillop et al., 2011). Whether texting while driving should be regarded as what we call “behavioral addiction” (Ascher and Levounis, 2015) is beyond the scope of this paper; however, the similarity between texting while driving and other addictive and impulsive behaviors suggests that approaches that are

shown to be effective for these behaviors may also be effective for texting while driving (see Hayashi et al., 2015; for potential intervention strategies for texting while driving).

Both hyperbolic and hyperboloid delay-discounting functions posit that the rate of discounting decreases as delay increases and can predict preference reversals. The exponential function, on the other hand, posits that the rate of discounting decreases constantly as delay increases and can predict preference reversals only if the rate of discounting of smaller-sooner rewards is assumed to be greater than that of larger-later rewards (Green et al., 1981). This assumption is valid with humans (magnitude effects; Green et al., 1997) but not with nonhumans (Madden and Johnson, 2010). In addition, although the exponential function is a popular normative model of economic behavior, previous research has documented systematic deviation from the exponential discounting in humans (e.g., Green et al., 1994; Kirby, 1997; Rachlin et al., 1991), including individuals addicted to drugs (e.g., Bickel et al., 1999; Madden et al., 1999). The present study is consistent with these previous studies, indicating that delay discounting of an opportunity to reply to a text message while driving conform to a hyperbolic function. Collectively, preference reversal may be essential for understanding the self-control failure in texting while driving, and the good fit of the data to the hyperbolic equation supports the conclusion that hyperbolic discounting is an important process involved in texting while driving.

4.2. Limitations

Several limitations of the present study need to be discussed. First, both delay discounting tasks involved hypothetical outcomes. Therefore, it is possible that participants' choices do not reflect the actual choices if the outcomes had been real. Indeed, previous research on risk-taking has shown that individuals tend to take more risks when outcomes are hypothetical than when they are real (e.g., Irwin et al., 1992); however, it would be ethically problematic to let participants actually reply to text messages while they are driving. In addition, numerous studies with delay discounting of monetary rewards suggest that hypothetical and real monetary rewards produce similar results (Baker et al., 2003; Bickel et al., 2009; Johnson and Bickel, 2002; Johnson et al., 2007; Lagorio and Madden, 2005; Madden et al., 2003, 2004). These studies established the validity of using hypothetical monetary rewards and the same may be true for the delay discounting of a hypothetical opportunity to reply to a text message.

Second, self-reported data were used to measure the frequency and days of texting while driving. Previous research has documented the tendency to underreport socially inappropriate behavior (Wentland, 1993). It is important to conduct naturalistic driving studies that involve observational data of actual texting behavior, perhaps using an on-board camera (e.g., Klauer et al., 2014). Another possibility would be to use a software that automatically records the number of text messages read and sent while driving, although it is technologically very difficult to separately count text messages read and sent as a driver or as a passenger. Nevertheless, to fully validate this novel delay discounting procedure, conducting naturalistic driving studies in some way would be an important future direction.

Third, the sample size was relatively small and the sample exclusively consisted of college students. Certainly, a larger and more diverse sample would be ideal and future research

should utilize such a sample. This is particularly important to establish external validity of the present study. Given the exploratory nature of the present study, however, the relatively small sample size may be justified. In addition, although the exclusive use of college students was employed for the sake of convenience, it is important to note that college students are indeed an important target population who is at risk for texting while driving. In this sense, the exclusive use of college students may be considered as both a limitation and a strength of the present study (cf. Feldman et al., 2011).

Finally, it is important to note that decisions to engage in texting while driving should stem from biases in not only delayed outcomes but also probabilistic outcomes (i.e., under- or over-estimating the probability of motor vehicle crashes). The discounting task in the present study could be modified to assess probability discounting—the subjective devaluation of a reward or an aversive outcome as a function of the probability of its occurrence (Green and Myerson, 2010). Perhaps the decision to engage in texting while driving is a function of both types of discounting. As an initial step to develop the novel discounting procedure, the present study addressed only delay discounting, but future research should address probability discounting as well.

4.3. Conclusion and future research

In the present study, the rate of delay discounting of the hypothetical opportunity to text while driving was significantly correlated with participants' self-reported days and frequency of texting while driving. This finding suggests that the novel delay discounting task developed in the present study has predictive validity. More studies are needed to further test the validity of this task. For example, construct validity of the present task should be assessed by testing whether the task is sensitive to variables known to affect rates of discounting, such as magnitude of rewards (i.e., larger rewards are discounted less; e.g., Green et al., 1997). Also, testing whether rates of discounting in the present task correlated with other relevant measures, such as cellphone dependency (Billieux et al., 2007; Igarashi et al., 2008) or frequency of distracted driving (Bergmark et al., 2016), is also important to further validate the present task.

The present results support the possibility that delay discounting effectively models the choice between immediate text messaging versus waiting until arriving at a destination. Accordingly, a delay discounting task may serve as a useful research tool (cf. Sigurdsson et al., 2013) that allows for the investigation of other variables that might affect texting while driving. These variables may include those associated with drivers (e.g., personality trait), the sender (e.g., closeness of the relationship, importance of the message), or environmental conditions (e.g., traffic, weather). The task may also be adapted for studying delay discounting associated with other forms of texting while driving (e.g., reading or initiating a text message), other uses of mobile electronic devices (e.g., voice, email, and social media), and even other forms of distracted driving (e.g., eating and drinking).

An understanding of the variables that influence the decision to text while driving is fundamental to the prevention and reduction of the problem. The research tool can be used to reveal important variables that lead not only to more effective prevention strategies but also to the development of promising solutions that can reduce texting while driving. For

example, the effectiveness of an intervention that is shown to be effective for other impulsivity-related problems can be tested using this delay discounting procedure as a research tool. An example of such an intervention is the one that uses episodic *future thinking*, which refers to “an ability to project the self forward in time to pre-experience an event” (Atance and O’Neill, 2001; p. 537). Engaging in episodic future thinking leads to a more salient representation of the event imagined. Several previous studies have investigated therapeutic effects of episodic future thinking on altering discounting rates, and demonstrated that individuals who engaged in episodic future thinking made less impulsive choices (Daniel et al., 2015; Dassen et al., 2016; Kaplan et al., 2016). The effectiveness of episodic future thinking in reducing texting while driving can be tested using the delay discounting procedure developed in the present study.

In conclusion, the present study supports the notion that texting while driving is fundamentally an impulsive choice—the choice to text while driving results in instant at the expense of safety. It was also shown that delay discounting may be a useful paradigm for better understanding this at-risk behavior. Although the delay discounting task developed in the present study requires further validation, the task shows promise for elucidating the important variables responsible for texting while driving as well as for evaluating effective intervention strategies.

Acknowledgments

The present study was supported by Undergraduate Research Grant from Office of Academic Affairs at Pennsylvania State University, Hazleton. We would like to thank Michael Andrew for his comments on earlier versions of this paper. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

References

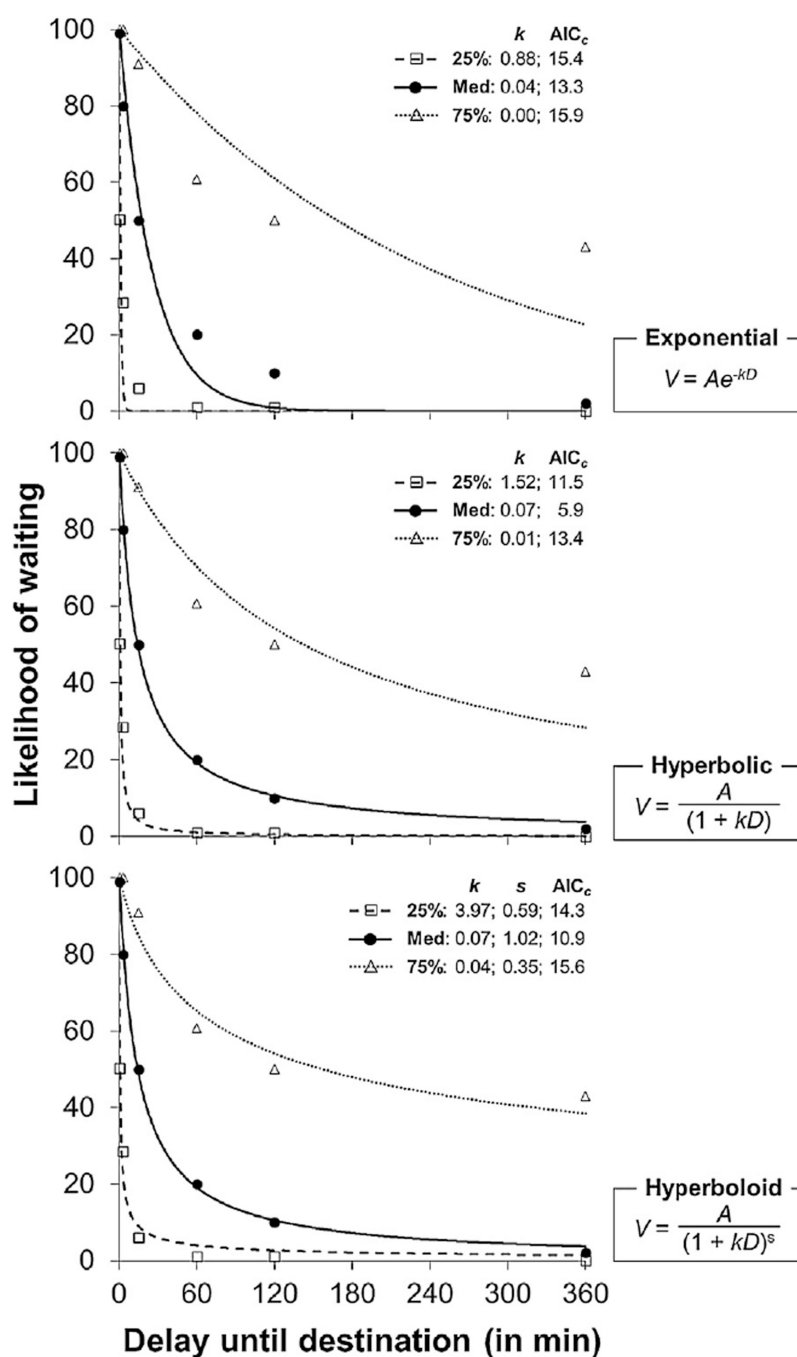
- Arantes J, Berg ME, Lawlor D, Grace RC. Offenders have higher delay-discounting rates than non-offenders after controlling for differences in drug and alcohol abuse. *Legal Criminol. Psychol.* 2013; 18:240–253. <http://dx.doi.org/10.1111/j.2044-8333.2012.02052.x>.
- Ascher, MS.; Levounis, P., editors. *The Behavioral Addictions*. Arlington, VA: American Psychiatric Publishing; 2015.
- Atance CM, O’Neill DK. Episodic future thinking. *Trends Cognit. Sci.* 2001:533–539. [http://dx.doi.org/10.1016/s1364-6613\(00\)01804-0](http://dx.doi.org/10.1016/s1364-6613(00)01804-0). [PubMed: 11728911]
- Atchley P, Warden AC. The need of young adults to text now: using delay discounting to assess informational choice. *J. Appl. Res. Memory Cognit.* 2012; 1:229–234. <http://dx.doi.org/10.1016/j.jarmac.2012.09.001>.
- Atchley P, Atwood S, Boulton A. The choice to text and drive in younger drivers: behavior may shape attitude. *Accid. Anal. Prev.* 2011; 43:134–142. <http://dx.doi.org/10.1016/j.aap.2010.08.003>. [PubMed: 21094307]
- Baker F, Johnson MW, Bickel WK. Delay discounting in current and never-before cigarette smokers: similarities and differences across commodity, sign, and magnitude. *J. Abnormal Psychol.* 2003; 112:382–392. <http://dx.doi.org/10.1037/0021-843X.112.3.382>.
- Bayer JB, Campbell SW. Texting while driving on automatic: considering the frequency-independent side of habit. *Comp. Hum. Behav.* 2012; 28:2083–2090. <http://dx.doi.org/10.1016/j.chb.2012.06.012>.
- Bergmark RW, Gliklich E, Guo R, Gliklich RE. Texting while driving: the development and validation of the distracted driving survey and risk score among young adults. *Inj. Epidemiol.* 2016; 3(1) <http://dx.doi.org/10.1186/s40621-016-0073-8>.

- Bickel WK, Marsch LA. Toward a behavioral economic understanding of drug dependence: delay discounting processes. *Addiction*. 2001; 96:73–86. <http://dx.doi.org/10.1046/j.1360-0443.2001.961736.x>. [PubMed: 11177521]
- Bickel WK, Odum AL, Madden GJ. Impulsivity and cigarette smoking: delay discounting in current, never, and ex-smokers. *Psychopharmacology*. 1999; 146:447–454. <http://dx.doi.org/10.1007/PL00005490>. [PubMed: 10550495]
- Bickel WK, Pitcock JA, Yi R, Angtuaco EJ. Congruence of BOLD response across intertemporal choice conditions: fictive and real money gains and losses. *J. Neurosci*. 2009; 29:8839–8846. <http://dx.doi.org/10.1523/JNEUROSCI.5319-08.2009>. [PubMed: 19587291]
- Bickel WK, Jarmolowicz DP, Mueller ET, Koffarnus MN, Gatchalian KM. Excessive discounting of delayed reinforcers as a trans-disease process contributing to addiction and other disease-related vulnerabilities: emerging evidence. *Pharmacol. Ther*. 2012; 134:287–297. <http://dx.doi.org/10.1016/j.pharmthera.2012.02.004>. [PubMed: 22387232]
- Bickel WK, Johnson MW, Koffarnus MN, MacKillop J, Murphy JG. The behavioral economics of substance use disorders: reinforcement pathologies and their repair. *Annu. Rev. Clin. Psychol*. 2014; 10:641–677. <http://dx.doi.org/10.1146/annurev-clinpsy-032813-153724>. [PubMed: 24679180]
- Billieux J, Van der Linden M, d'Acremont M, Ceschi G, Zermatten A. Does impulsivity relate to perceived dependence on and actual use of the mobile phone? *Appl. Cognit. Psychol*. 2007; 21:527–537. <http://dx.doi.org/10.1002/acp.1289>.
- Burnham, KP.; Anderson, DR. *Model Selection and Multimodel Inference: A Practical Information theoretic Approach*. 2nd. New York: Springer-Verlag; 2002.
- Centers for Disease Control and Prevention. Mobile device use while driving—United States and seven European countries, 2011. 2013. Retrieved from <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6210a1.htm>
- Charlton SR, Fantino E. Commodity specific rates of temporal discounting: does metabolic function underlie differences in rates of discounting? *Behav. Process*. 2008; 77:334–342. <http://dx.doi.org/10.1016/j.beproc.2007.08.002>.
- Chesson HW, Leichliter JS, Zimet GD, Rosenthal SL, Bernstein DI, Fife KH. Discount rates and risky sexual behaviors among teenagers and young adults. *J. Risk Uncertainty*. 2006; 32:217–230. <http://dx.doi.org/10.1007/s11166-006-9520-1>.
- Daniel TO, Said M, Stanton CM, Epstein LH. Episodic future thinking reduces delay discounting and energy intake in children. *Eating Behav*. 2015; 18:20–24. <http://dx.doi.org/10.1016/j.eatbeh.2015.03.006>.
- Dassen FCM, Jansen A, Nederkoorn C, Houben K. Focus on the future: episodic future thinking reduces discount rate and snacking. *Appetite*. 2016; 96:327–332. <http://dx.doi.org/10.1016/j.appet.2015.09.032>. [PubMed: 26431684]
- Ehsani JP, Bingham CR, Ionides E, Childers D. The impact of Michigan's text messaging restriction on motor vehicle crashes. *J. Adolesc. Health*. 2014; 54:S68–S74. <http://dx.doi.org/10.1016/j.jadohealth.2014.01.003>. [PubMed: 24759444]
- Epstein LH, Salvy SJ, Carr KA, Dearing KK, Bickel WK. Food reinforcement, delay discounting and obesity. *Physiol. Behav*. 2010; 100:438–445. <http://dx.doi.org/10.1016/j.physbeh.2010.04.029>. [PubMed: 20435052]
- Feldman G, Greeson J, Renna M, Robbins-Monteith K. Mindfulness predicts less texting while driving among young adults: examining attention- and emotion-regulation motives as potential mediators. *Personality Individual Differences*. 2011; 51:856–861. <http://dx.doi.org/10.1016/j.paid.2011.07.020>. [PubMed: 22031789]
- Goodwin AH, O'Brien NP, Foss RD. Effect of North Carolina's restriction on teenage driver cell phone use two years after implementation. *Accid. Anal. Prev*. 2012; 48:363–367. <http://dx.doi.org/10.1016/j.aap.2012.02.006>. [PubMed: 22664702]
- Governors Highway Safety Association. Distracted driving laws. 2016 Retrieved from http://www.ghsa.org/html/stateinfo/laws/cellphone_laws.html.
- Green L, Myerson J. Exponential versus hyperbolic discounting of delayed outcomes: risk and waiting time. *Am. Zool*. 1996; 36:496–505. <http://dx.doi.org/10.1093/icb/36.4.496>.

- Green L, Myerson J. A discounting framework for choice with delayed and probabilistic rewards. *Psychol. Bull.* 2004; 130:769–792. <http://dx.doi.org/10.1037/0033-2909.130.5.769>. [PubMed: 15367080]
- Green, L.; Myerson, J. Experimental and correlational analyses of delay and probability discounting. In: Madden, GJ.; Bickel, WK., editors. *Impulsivity: The Behavioral and Neurological Science of Discounting*. Washington, DC: American Psychological Association; 2010. p. 67–92.
- Green L, Fisher EB, Perlow S, Sherman L. Preference reversal and self control: choice as a function of reward amount and delay. *Behaviour Analysis Letters*. 1981; 1:43–51.
- Green L, Fry AF, Myerson J. Discounting of delayed rewards: a life-span comparison. *Psychol. Sci.* 1994; 5:33–36. <http://dx.doi.org/10.1111/j.1467-9280.1994.tb00610.x>.
- Green L, Myerson J, Mcfadden E. Rate of temporal discounting decreases with amount of reward. *Memory Cognit.* 1997; 25:715–723. <http://dx.doi.org/10.3758/BF03211314>.
- Hayashi Y, Russo CT, Wirth O. Texting while driving as impulsive choice: a behavioral economic analysis. *Accid. Anal. Prev.* 2015; 83:182–189. <http://dx.doi.org/10.1016/j.aap.2015.07.025>. [PubMed: 26280804]
- Herrmann ES, Hand DJ, Johnson MW, Badger GJ, Heil SH. Examining delay discounting of condom-protected sex among opioid-dependent women and non-drug-using control women. *Drug Alcohol Depend.* 2014; 144:53–60. <http://dx.doi.org/10.1016/j.drugalcdep.2014.07.026>. [PubMed: 25190049]
- Igarashi T, Motoyoshi T, Takai J, Yoshida T. No mobile, no life: self-perception and text-message dependency among Japanese high school students. *Comp. Hum. Behav.* 2008; 24:2311–2324. <http://dx.doi.org/10.1016/j.chb.2007.12.001>.
- Irwin JR, McClelland GH, Schulze WD. Hypothetical and real consequences in experimental auctions for insurance against low-probability risks. *J. Behav. Decis. Making.* 1992; 5:107–116. <http://dx.doi.org/10.1002/bdm.3960050203>.
- Johnson MW, Bickel WK. Within-subject comparison of real and hypothetical money rewards in delay discounting. *J. Exp. Anal. Behav.* 2002; 77:129–146. <http://dx.doi.org/10.1901/jeab.2002.77-129>. [PubMed: 11936247]
- Johnson MW, Bickel WK. An algorithm for identifying nonsystematic delay-discounting data. *Exp. Clin. Psychopharmacol.* 2008; 16:264–274. <http://dx.doi.org/10.1037/1064-1297.16.3.264>. [PubMed: 18540786]
- Johnson MW, Bruner NR. The sexual discounting task: HIV risk behavior and the discounting of delayed sexual rewards in cocaine dependence. *Drug Alcohol Depend.* 2012; 123:15–21. <http://dx.doi.org/10.1016/j.drugalcdep.2011.09.032>. [PubMed: 22055012]
- Johnson MW, Bruner NR. Test-retest reliability and gender differences in the sexual discounting task among cocaine-dependent individuals. *Exp. Clin. Psychopharmacol.* 2013; 21:277–286. <http://dx.doi.org/10.1037/a0033071>. [PubMed: 23834552]
- Johnson MW, Bickel WK, Baker F. Moderate drug use and delay discounting: a comparison of heavy, light, and never smokers. *Exp. Clin. Psychopharmacol.* 2007; 15:187–194. <http://dx.doi.org/10.1037/1064-1297.15.2.187>. [PubMed: 17469942]
- Johnson MW, Bickel WK, Baker F, Moore BA, Badger GJ, Budney AJ. Delay discounting in current and former marijuana-dependent individuals. *Exp. Clin. Psychopharmacol.* 2010; 18:99–107. <http://dx.doi.org/10.1037/a0018333>. [PubMed: 20158299]
- Johnson MW, Johnson PS, Herrmann ES, Sweeney MM. Delay and probability discounting of sexual and monetary outcomes in individuals with cocaine use disorders and matched controls. *PLoS One.* 2015; 10(5):e0128641. <http://dx.doi.org/10.1371/journal.pone.0128641>. [PubMed: 26017273]
- Kaplan BA, Reed DD, Jarmolowicz DP. Effects of episodic future thinking on discounting: personalized age-progressed pictures improve risky long-term health decisions. *J. Appl. Behav. Anal.* 2016; 49:148–169. <http://dx.doi.org/10.1002/jaba.277>. [PubMed: 26679531]
- Kirby KN. Bidding on the future: evidence against normative discounting of delayed rewards. *J. Exp. Psychol. Gen.* 1997; 126:54–70. <http://dx.doi.org/10.1037/0096-3445.126.1.54>.

- Klauer SG, Guo F, Simons-Morton BG, Ouimet MC, Lee SE, Dingus TA. Distracted driving and risk of road crashes among novice and experienced drivers. *N. Eng. J. Med.* 2014; 370:54–59. <http://dx.doi.org/10.1056/NEJMs1204142>.
- Lagorio CH, Madden GJ. Delay discounting of real and hypothetical rewards III: steady-state assessments, forced-choice trials, and all real rewards. *Behav. Process.* 2005; 69:173–187. <http://dx.doi.org/10.1016/j.beproc.2005.02.003>.
- Lancaster K. An axiomatic theory of consumer time preference. *Int. Econ. Rev.* 1963; 4:221–231. <http://dx.doi.org/10.2307/2525488>.
- MacKillop J, Amlung MT, Few LR, Ray LA, Sweet LH, Munafò MR. Delayed reward discounting and addictive behavior: a meta-analysis. *Psychopharmacology.* 2011; 216:305–321. <http://dx.doi.org/10.1007/s00213-011-2229-0>. [PubMed: 21373791]
- Madden, GJ.; Bickel, WK. Introduction. In: Madden, GJ.; Bickel, WK., editors. *Impulsivity: The Behavioral and Neurological Science of Discounting*. American Psychological Association; Washington, DC: 2010. p. 3-8.
- Madden, GJ.; Johnson, PS. A delay-discounting primer. In: Madden, GJ.; Bickel, WK., editors. *Impulsivity: The Behavioral and Neurological Science of Discounting*. Washington, DC: American Psychological Association; 2010. p. 11-37.
- Madden GJ, Bickel WK, Jacobs EA. Discounting of delayed rewards in opioid-dependent outpatients: exponential or hyperbolic discounting functions? *Exp. Clin. Psychopharmacol.* 1999; 7:284–293. <http://dx.doi.org/10.1037/1064-1297.7.3.284>. [PubMed: 10472517]
- Madden GJ, Begotka AM, Raiff BR, Kastern LL. Delay discounting of real and hypothetical rewards. *Exp. Clin. Psychopharmacol.* 2003; 11:139–145. <http://dx.doi.org/10.1037/1064-1297.11.2.139>. [PubMed: 12755458]
- Madden GJ, Raiff BR, Lagorio CH, Begotka AM, Mueller AM, Hehli DJ, Wegener AA. Delay discounting of potentially real and hypothetical rewards: II. Between- and within-subject comparisons. *Exp. Clin. Psychopharmacol.* 2004; 12:251–261. <http://dx.doi.org/10.1037/1064-1297.12.4.251>. [PubMed: 15571442]
- Mazur, JE. An adjusting procedure for studying delayed reinforcement. In: Commons, ML.; Mazur, JE.; Nevin, JA.; Rachlin, H., editors. *Quantitative Analyses of Behavior: The Effect of Delay and of Intervening Events on Reinforcement Value*. Vol. 5. Hillsdale, NJ: Erlbaum; 1987. p. 55-73.
- Musicant O, Lotan T, Albert G. Do we really need to use our smartphones while driving? *Accid. Anal. Prev.* 2015; 85:13–21. <http://dx.doi.org/10.1016/j.aap.2015.08.023>. [PubMed: 26364139]
- Myerson J, Green L. Discounting of delayed rewards: models of individual choice. *J. Exp. Anal. Behav.* 1995; 64:263–276. <http://dx.doi.org/10.1901/jeab.1995.64-263>. [PubMed: 16812772]
- Myerson J, Green L, Warusawitharana M. Area under the curve as a measure of discounting. *J. Exp. Anal. Behav.* 2001; 76:235–243. <http://dx.doi.org/10.1901/jeab.2001.76-235>. [PubMed: 11599641]
- National Safety Council. Annual estimate of cell phone crashes 2013. 2015 Retrieved from <http://www.nsc.org/DistractedDrivingDocuments/CPK/Attributable-Risk-Summary.pdf>.
- Odum AL, Madden GJ, Badger GJ, Bickel WK. Needle sharing in opioid-dependent outpatients: psychological processes underlying risk. *Drug Alcohol Depend.* 2000; 60:259–266. [http://dx.doi.org/10.1016/S0376-8716\(00\)00111-3](http://dx.doi.org/10.1016/S0376-8716(00)00111-3). [PubMed: 11053760]
- Odum AL. Delay discounting: I'm a k, you're a k. *J. Exp. Anal. Behav.* 2011a; 96:427–439. <http://dx.doi.org/10.1901/jeab.2011.96-423>. [PubMed: 22084499]
- Odum AL. Delay discounting: trait variable? *Behav. Process.* 2011b; 87:1–9. <http://dx.doi.org/10.1016/j.beproc.2011.02.007>.
- Petry, NM.; Madden, GJ. Discounting and pathological gambling. In: Madden, GJ.; Bickel, WK., editors. *Impulsivity: The Behavioral and Neurological Science of Discounting*. Washington, DC: American Psychological Association; 2010. p. 273-294.
- Quisenberry PN. Texting and driving: can it be explained by the general theory of crime? *Am. J. Criminal Justice.* 2015; 40:303–316. <http://dx.doi.org/10.1007/s12103-014-9249-3>.
- Rachlin H, Raineri A, Cross D. Subjective probability and delay. *J. Exp. Anal. Behav.* 1991; 55:233–244. <http://dx.doi.org/10.1901/jeab.1991.55-233>. [PubMed: 2037827]

- Rasmussen EB, Lawyer SR, Reilly W. Percent body fat is related to delay and probability discounting for food in humans. *Behav. Process.* 2010; 83:23–30. <http://dx.doi.org/10.1016/j.beproc.2009.09.001>.
- Reed DD, Becirevic A, Atchley P, Kaplan BA, Liese BS. Validation of a novel delay discounting of text messaging questionnaire. *Psychol. Rec.* 2016; 66:253–261. <http://dx.doi.org/10.1007/s40732-016-0167-2>.
- Samuelson PA. A note on measurement of utility. *Rev. Econ. Stud.* 1937; 4:155–161. <http://dx.doi.org/10.2307/2967612>.
- Saville BK, Gisbert A, Kopp J, Telesco C. Internet addiction and delay discounting in college students. *Psychol. Rec.* 2010; 60:273–286.
- Sherin KM, Lowe AL, Harvey BJ, Leiva DF, Malik A, Matthews S. American College of Preventive Medicine Prevention Practice Committee. Preventing texting while driving: a statement of the American College of Preventive Medicine. *Am. J. Preventive Med.* 2014; 47:681–688. <http://dx.doi.org/10.1016/j.amepre.2014.07.004>.
- Sigurdsson SO, Taylor MA, Wirth O. Discounting the value of safety: effects of perceived risk and effort. *J. Safety Res.* 2013; 46:127–134. <http://dx.doi.org/10.1016/j.jsr.2013.04.006>. [PubMed: 23932694]
- Spiess AN, Neumeyer N. An evaluation of R2 as an inadequate measure for nonlinear models in pharmacological and biochemical research: a Monte Carlo approach. *BMC Pharmacol.* 2010; 10:6. <http://dx.doi.org/10.1186/1471-2210-10-6>. [PubMed: 20529254]
- Struckman-Johnson C, Gaster S, Struckman-Johnson D, Johnson M, MayShinagle G. Gender differences in psychosocial predictors of texting while driving. *Accid. Anal. Prev.* 2015; 74:218–228. <http://dx.doi.org/10.1016/j.aap.2014.10.001>. [PubMed: 25463963]
- Takahashi T, Oono H, Radford MHB. Psychophysics of time perception and intertemporal choice models. *Phys. A: Stat. Mech. Appl.* 2008; 387:2066–2074. <http://dx.doi.org/10.1016/j.physa.2007.11.047>.
- Wentland, EJ. *Survey Responses: An Evaluation of Their Validity*. San Diego, CA: Academic Press; 1993.

**Fig. 1.**

Likelihood of waiting as a function of delay to the destination fitted to all three equations. The 25th percentile (25%), median (Med), and 75th percentile (75%) were calculated from aggregated group data ($N = 90$).

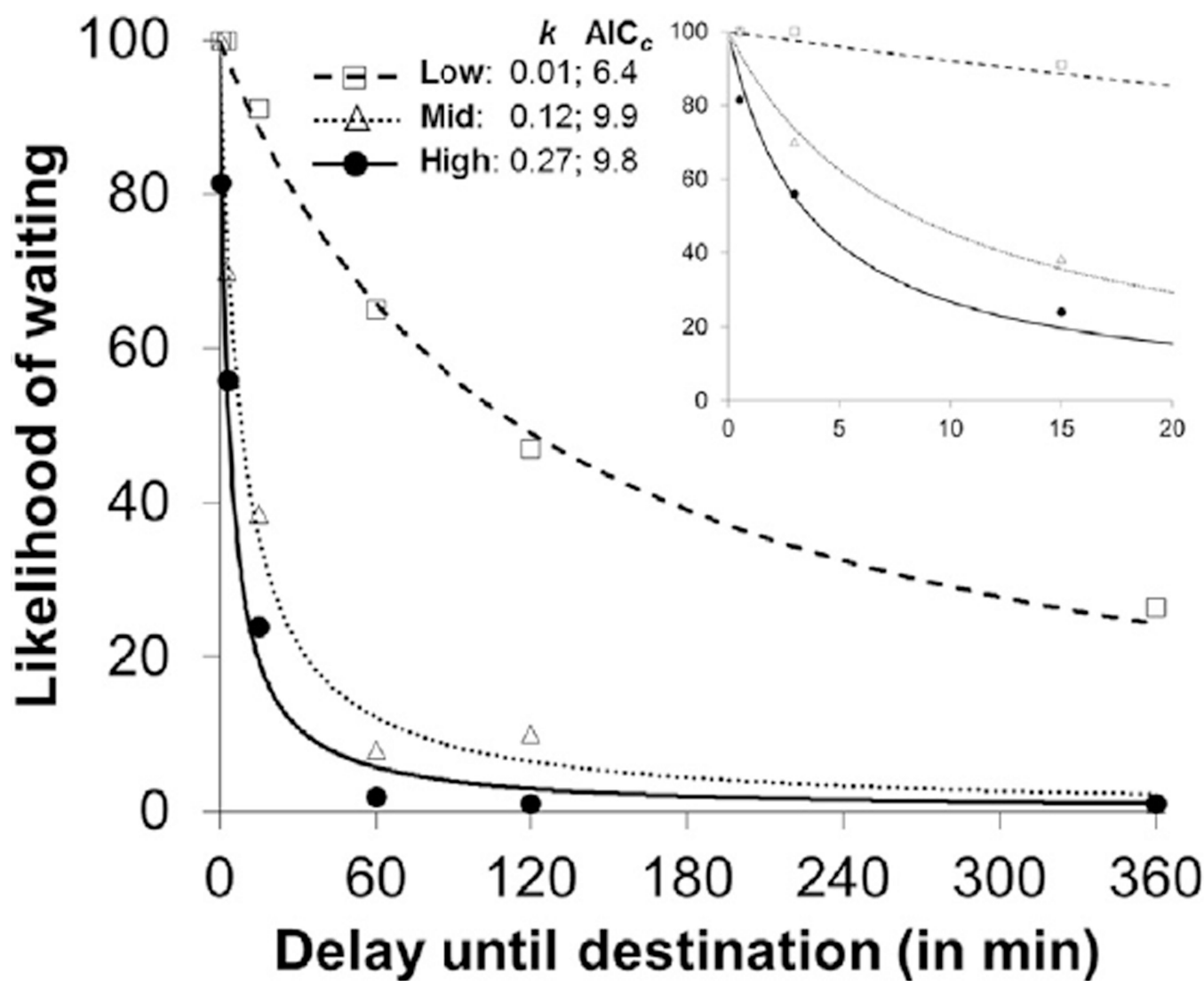


Fig. 2. Median likelihood of waiting as a function of delay to the destination for the three groups that differ in self-reported days of texting while driving ($N=30$ for each group). The inserted panel is provided to better illustrate the likelihood at small delays.

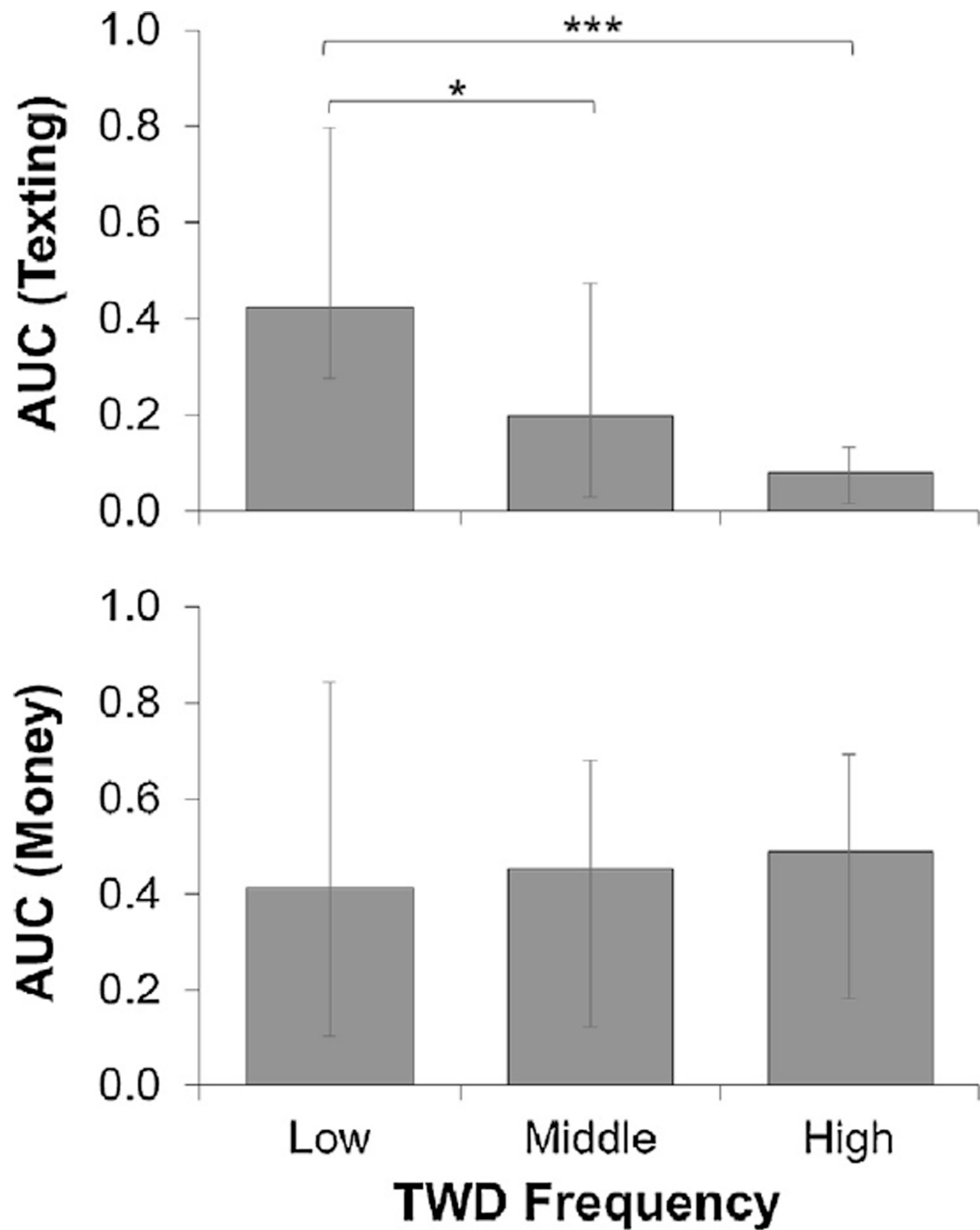


Fig. 3. Median area under the curve (AUC) of individual participants in three groups that differ in self-reported days of texting while driving. The upper and lower panels show the data on the likelihood of waiting until the destination and the subjective value of hypothetical monetary rewards, respectively. The error bars represent 25th and 75th percentiles. * $p < 0.05$. *** $p < 0.001$.

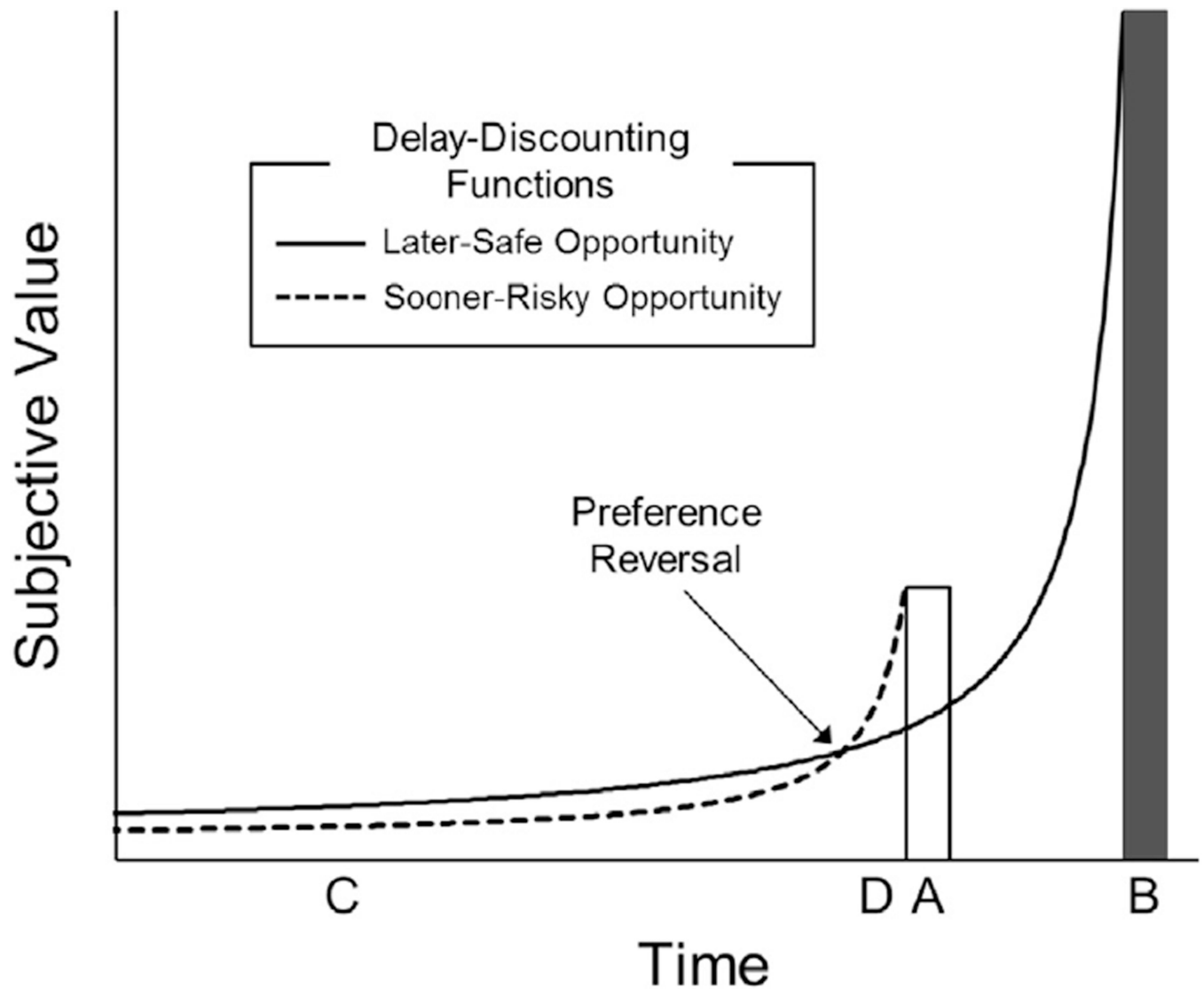


Fig. 4.

Hypothetical scenario for impulsive drivers with high rates of delay discounting. Time A depicts the moment when a sooner-risky opportunity is available (white bar), and Time B depicts the moment when a later-safe opportunity is available (black bar). Hypothetical delay-discounting functions are shown for the sooner-risky opportunity (dashed line) and the later-safe opportunity (solid line). At Time C, the availability of both opportunities is temporally remote, and thus drivers would place a greater value on the later-safe opportunity. At Time D, drivers place a greater value on the sooner-risky opportunity after a preference reversal.

Table 1

Demographic Characteristics for Three Groups.

Characteristics	Low TWD	Middle TWD	High TWD
Gender			
Male	8	15	14
Female	22	15	16
Age in years	19.5 (4.3)	19.9 (3.3)	19.8 (2.2)
Years of higher education	1.5 (1.0)	1.7 (1.0)	1.9 (1.3)
Years driving	3.1 (4.0)	3.7 (3.0)	3.8 (2.1)
Days of TWD ***	0.1 (0.3)	2.9 (1.8)	12.4 (5.4)
Frequency of TWD ***	1.9 (1.0)	2.7 (1.2)	4.2 (1.2)
Danger of TWD	6.8 (0.5)	6.4 (0.7)	6.2 (1.0)

Note. Values are means (and standard deviations) except for Gender.

TWD = Texting While Driving.

 $p < 0.001$.

Table 2
Pearson Correlation Coefficients of Demographic Characteristics and Measures on Texting While Driving.

	1	2	3	4	5	6	7	8	9
1. Age in years	–								
2. Gender (F = 0; M = 1)	0.08	–							
3. Years of higher education	0.64***	0.09	–						
4. Years driving	0.96***	0.04	0.61***	–					
5. Days of TWD	–0.05	0.20	0.06	–0.02	–				
6. Frequency of TWD	–0.07	0.10	0.06	–0.01	0.65***	–			
7. Danger of TWD	0.13	–0.29**	–0.06	0.13	–0.32**	–0.15	–		
8. AUC (texting)	0.05	–0.09	0.01	–0.04	–0.42***	–0.45***	0.17	–	
9. AUC (money)	0.14	–0.08	–0.02	0.14	0.05	0.06	–0.09	0.09	–

**
 $p < 0.01$.

 $p < 0.001$.